A Climatology of Midlatitude Continental Clouds from the ARM SGP Central Facility:

Part II: Cloud fraction and radiative forcing

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Acknowledgement:

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Goals:

(1) What are the seasonal, monthly, and diurnal variations of total, and single-layer low, middle, and high cloud amounts at the ARM SGP site?

(2) What are the impacts of these clouds on the surface radiation budget ?

Time period:

From January 1997 to December 2002

Data and Methods

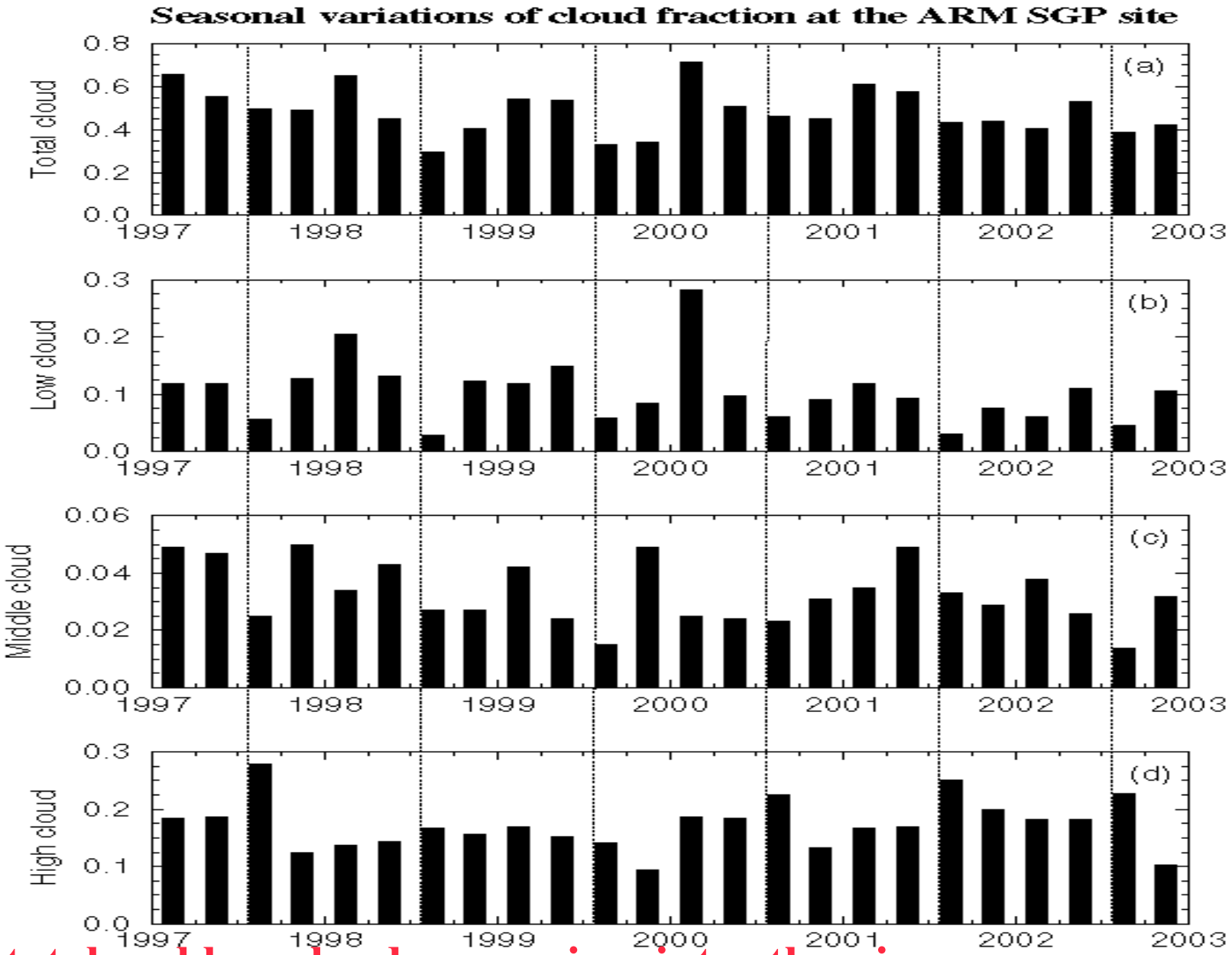
- Cloud radar/lidar to identify clear-sky, and cloudy periods.
- Total clouds include all clouds
- Single-layer clouds
  - Low cloud (top ≤3km, no higher clouds above it)
  - Middle cloud (3km ≤ cloud ≤ 6km;
    No higher clouds above and lower clouds below it)
  - High cloud (base > 6km, no lower clouds below it)

Data and Methods (cont.)

- The Best Estimate Flux Value Added Product (VAP) (Shi and Long 2002) for studying SW and LW fluxes and their CRFs.
- $CRF_{SW}=\langle Q\rangle_{cldy}-\langle Q\rangle_{clear}$;
  $CRF_{LW}=\langle F\rangle_{cldy}-\langle F\rangle_{clear}$;
  $CRF_{NET}=CRF_{SW}+CRF_{LW}$

where $\langle Q\rangle_{cldy}$ and $\langle F\rangle_{cldy}$ are net SW flux (down-up) and net LW flux during cloudy

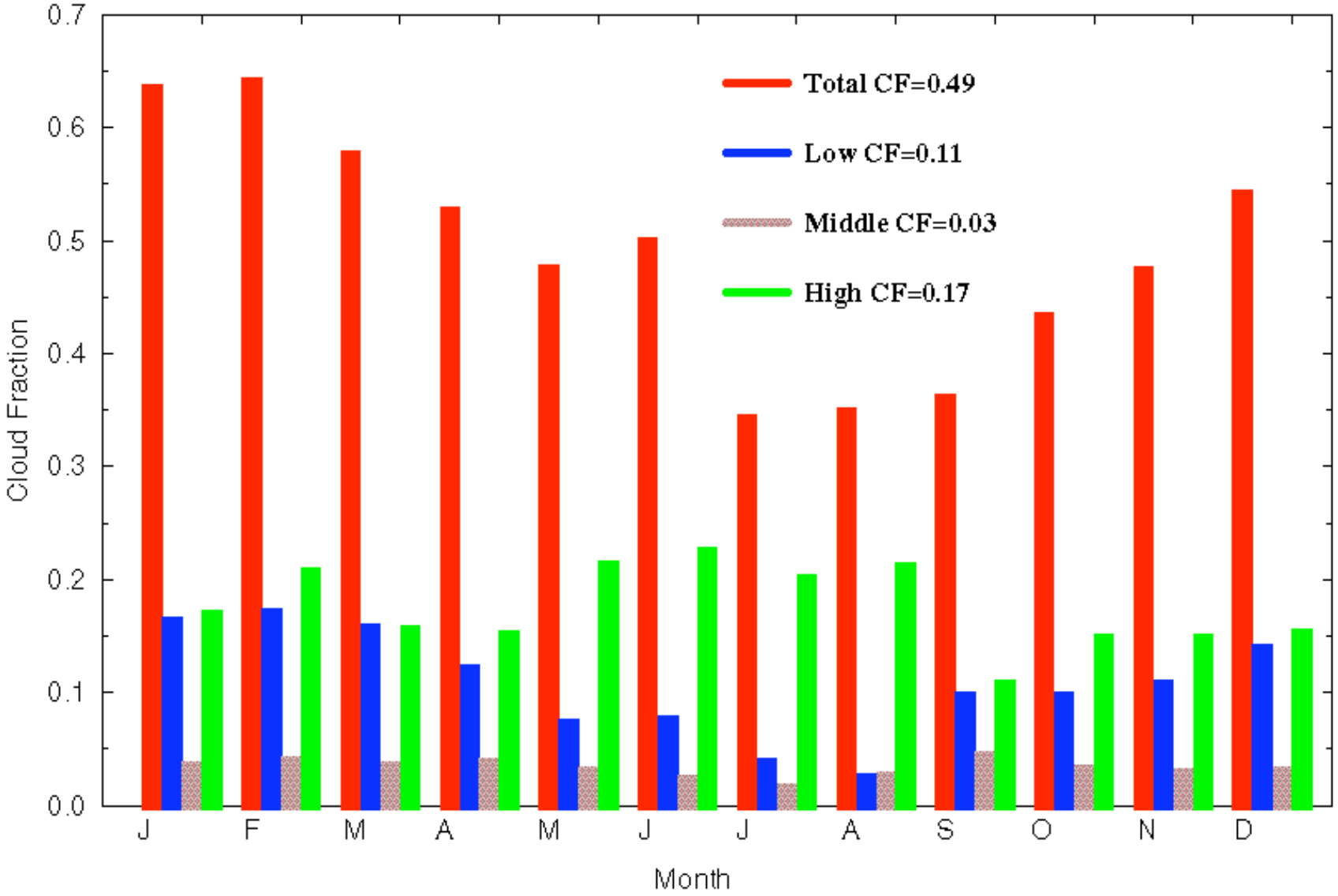
$\langle Q\rangle_{clear}$ and $\langle F\rangle_{clear}$ are net SW flux (down-up) net LW flux during clear sky.



For total and low clouds, more in winter than in summer.

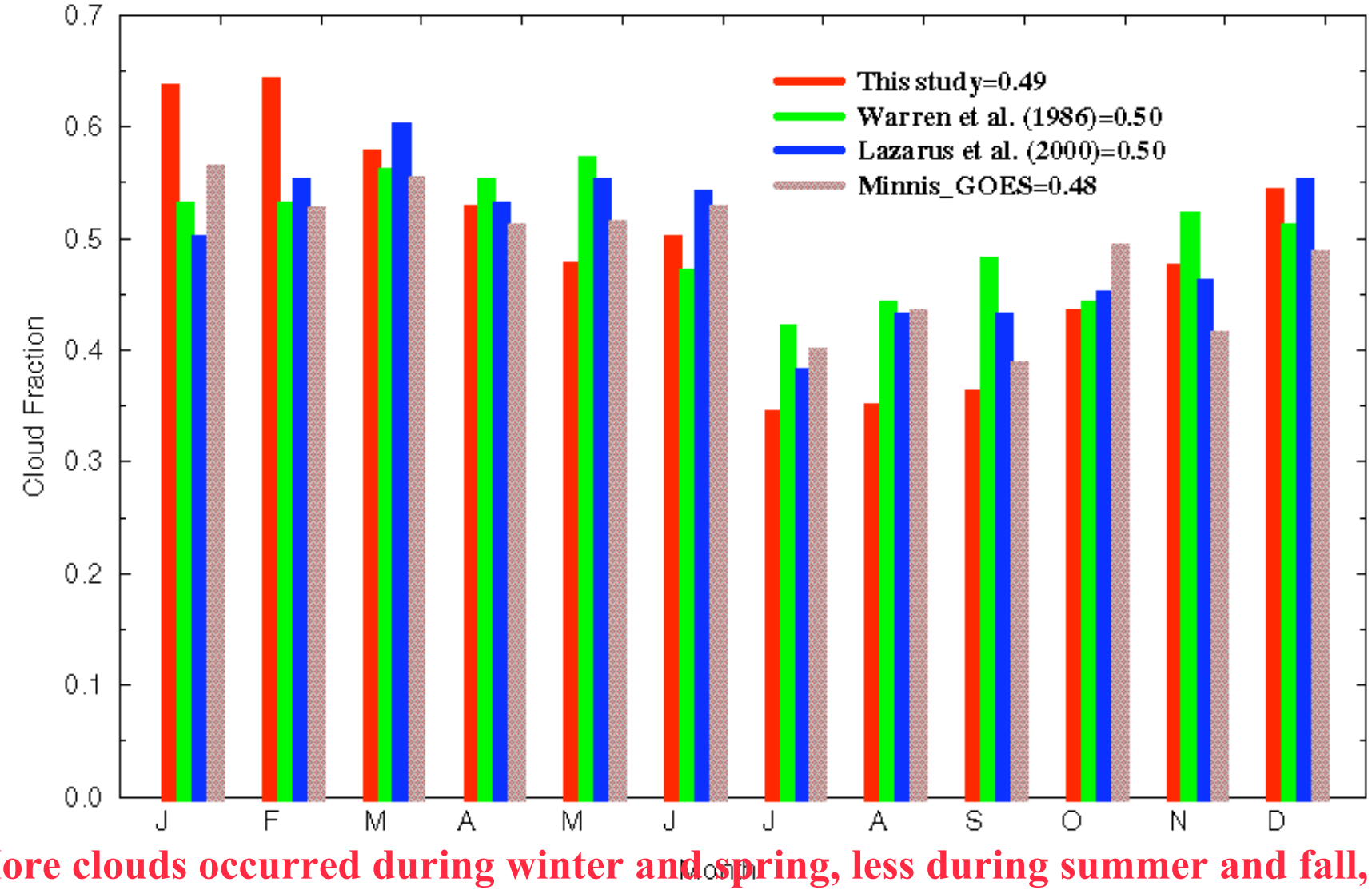
High clouds occur most and more in summer, middle clouds least

Monthly variations of cloud fraction at the ARM SGP Site



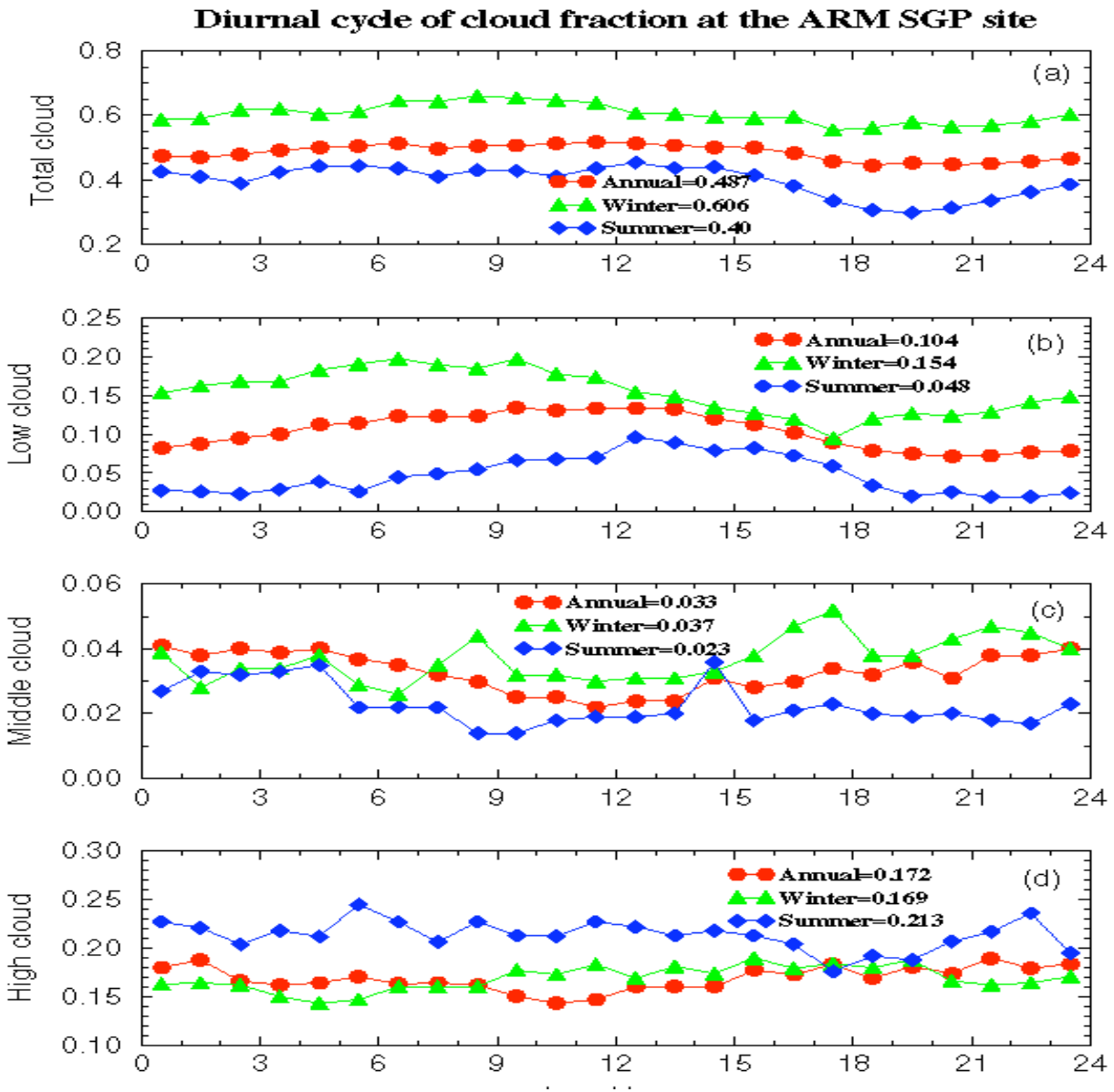
For total/low clouds, maxima from December to March, minima in July-Aug.
High clouds mirror the variation of low clouds with a local max. from May to Aug.

Comparison of total cloud fraction at the ARM SGP Site

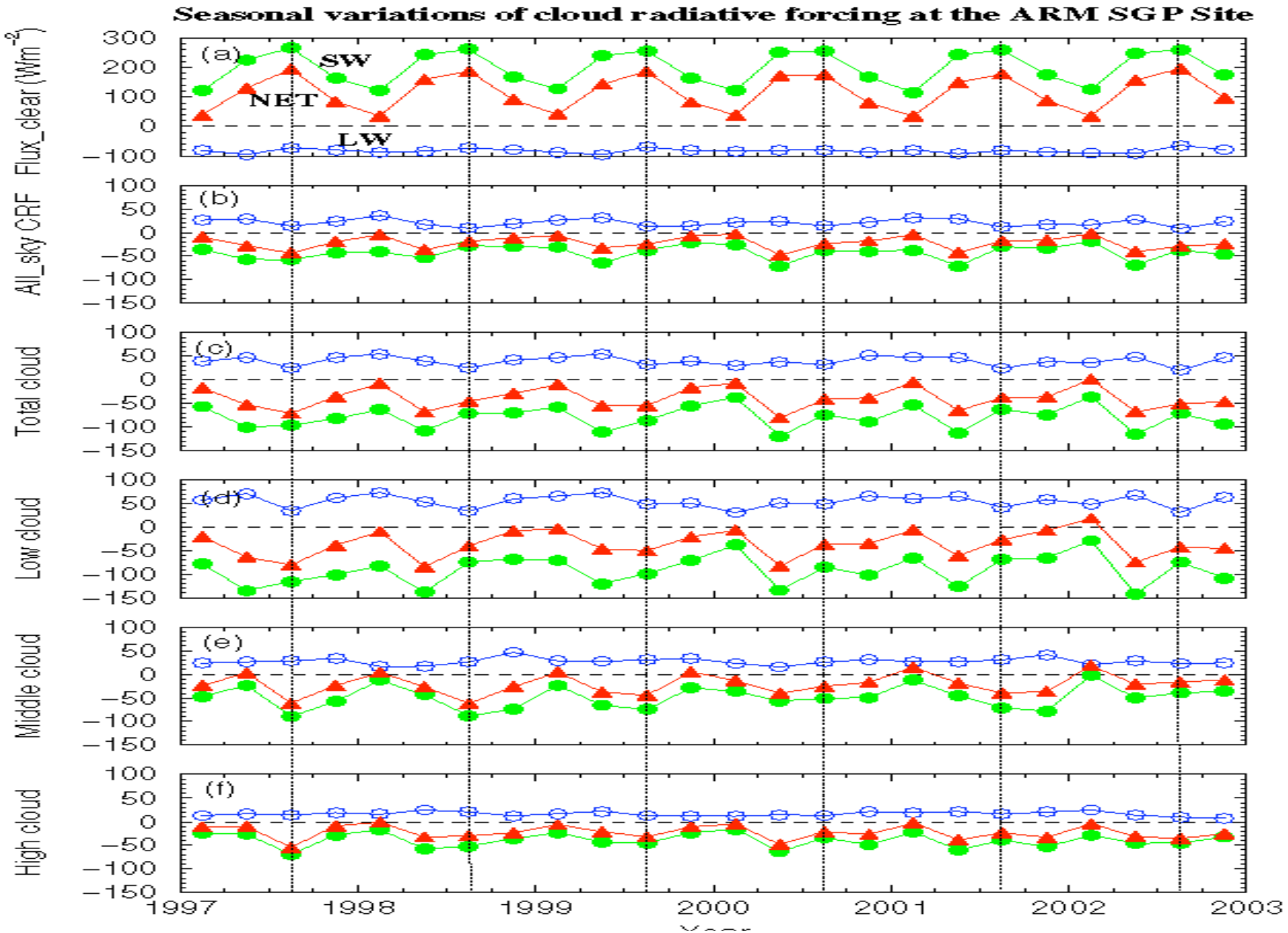


More clouds occurred during winter and spring, less during summer and fall, and big drops from June to July.

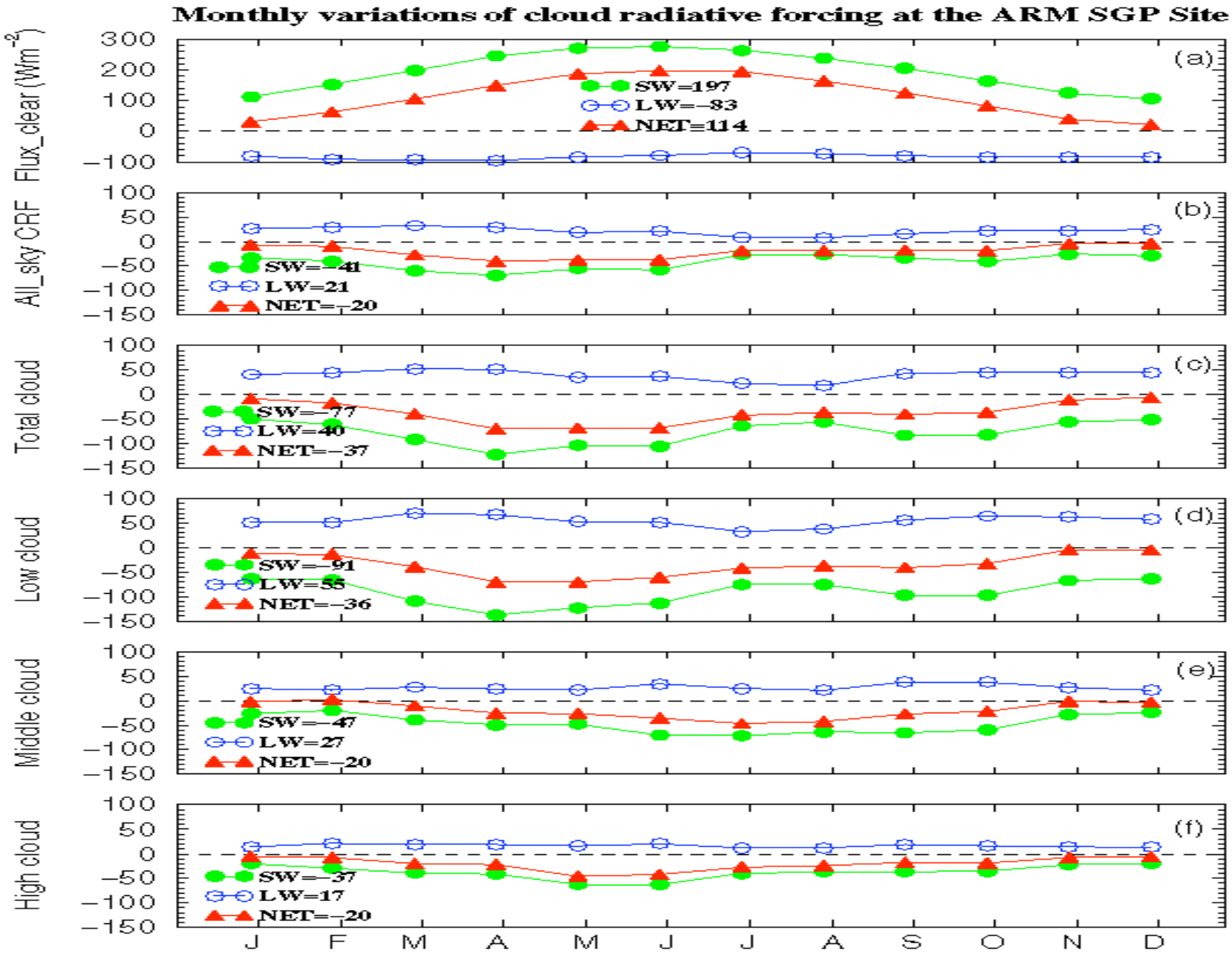
Conclusion: Total cloud fraction in this study represents a statistical value at SGP.



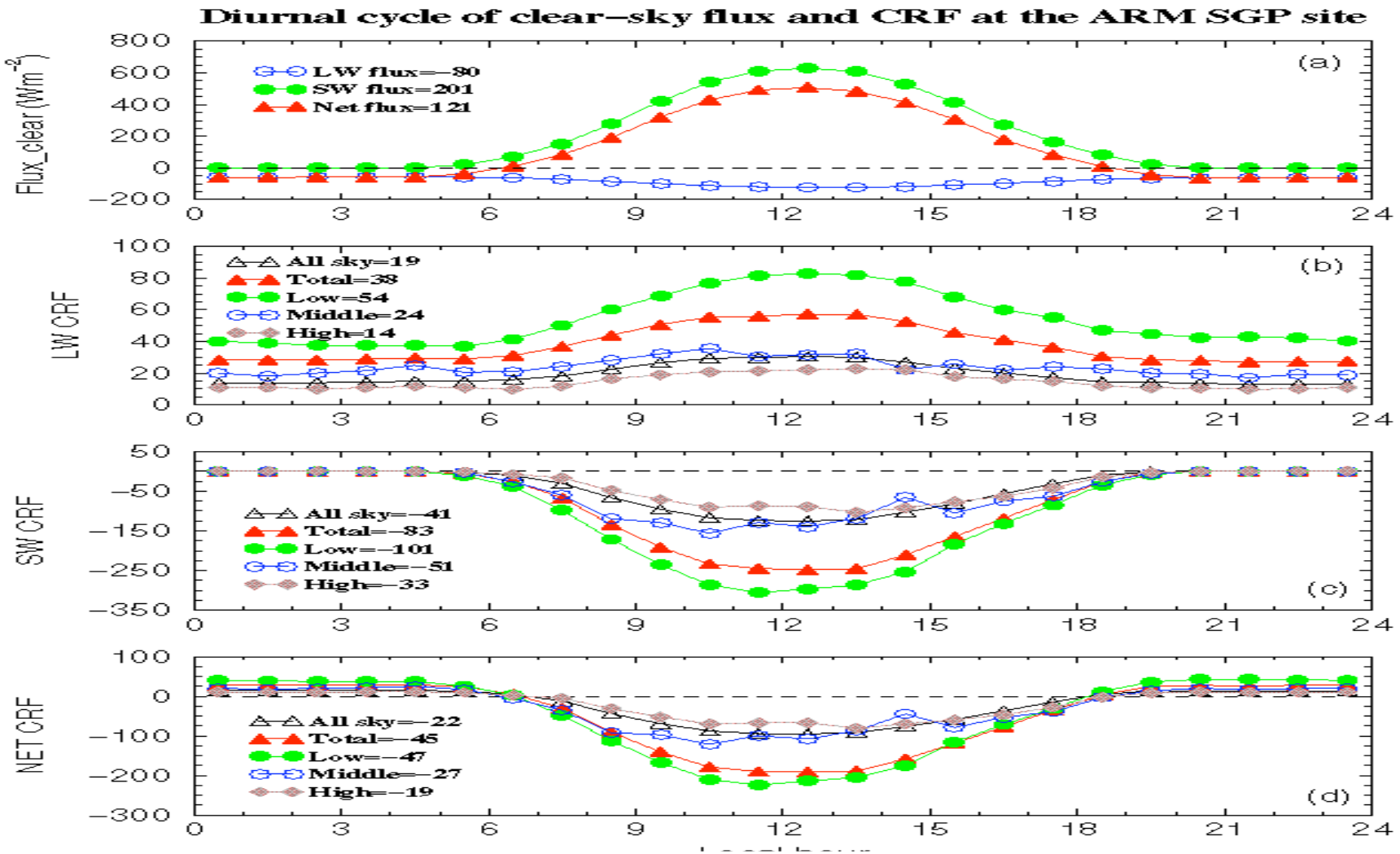
Annual/summer total and low clouds increase from midnight to local noon, then decrease to 1930 LT, during winter they have max. in mid-morning, min. in early evening. Annual/winter high clouds increase from 0300 to 1930 LT, then decrease



For all_sky/total/low clouds: their CRFs are similar with increased amplitudes, min. LW CRFs in summer, largest negative SW/NET CRFs in spring, smallest in winter. High_cloud CRFs mimic all_sky CRFs.

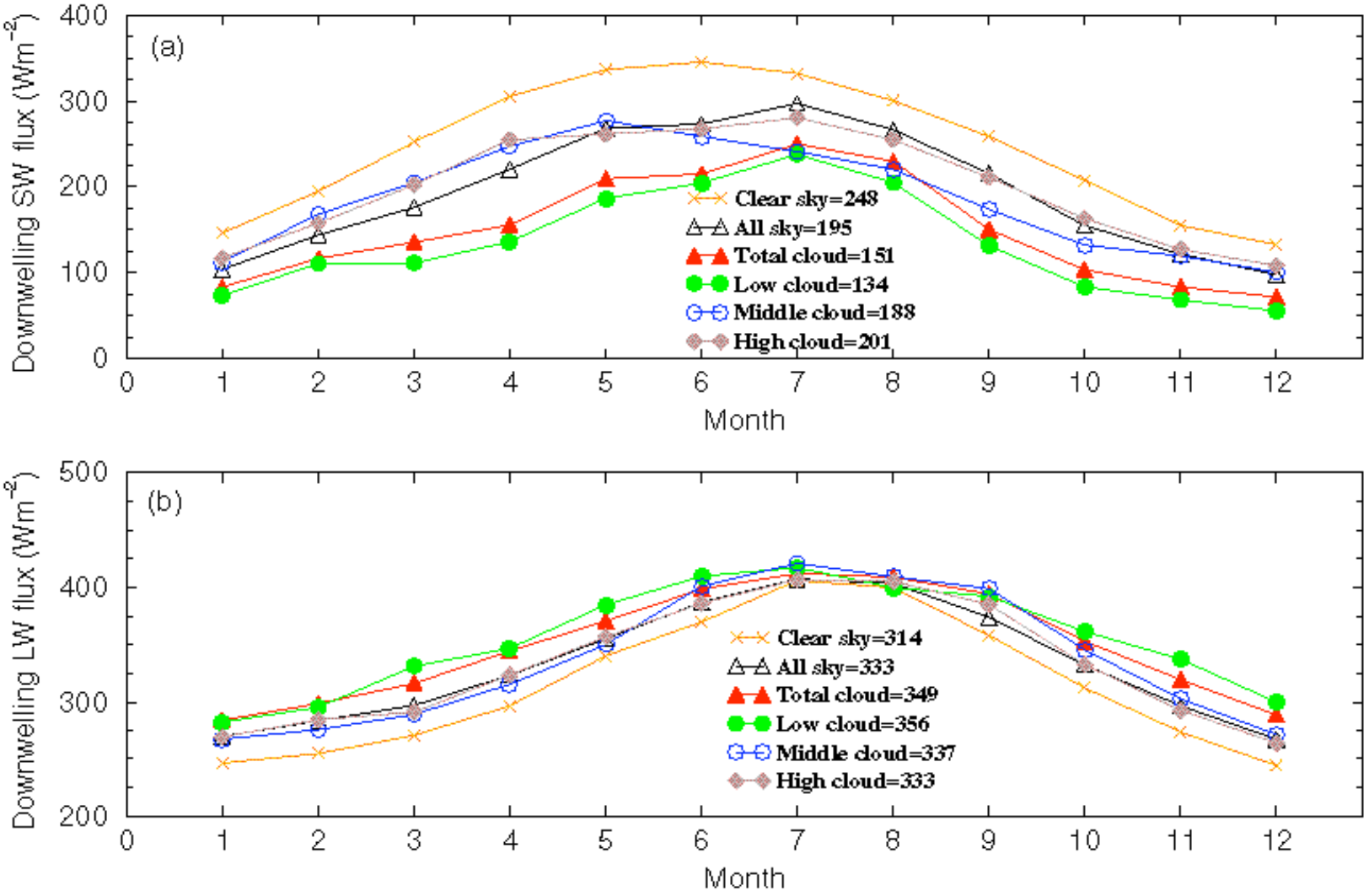


November-February is least NET CRFs for all clouds; April is greatest negative for all sky, total and low clouds; July for middle clouds, May-June for high clouds

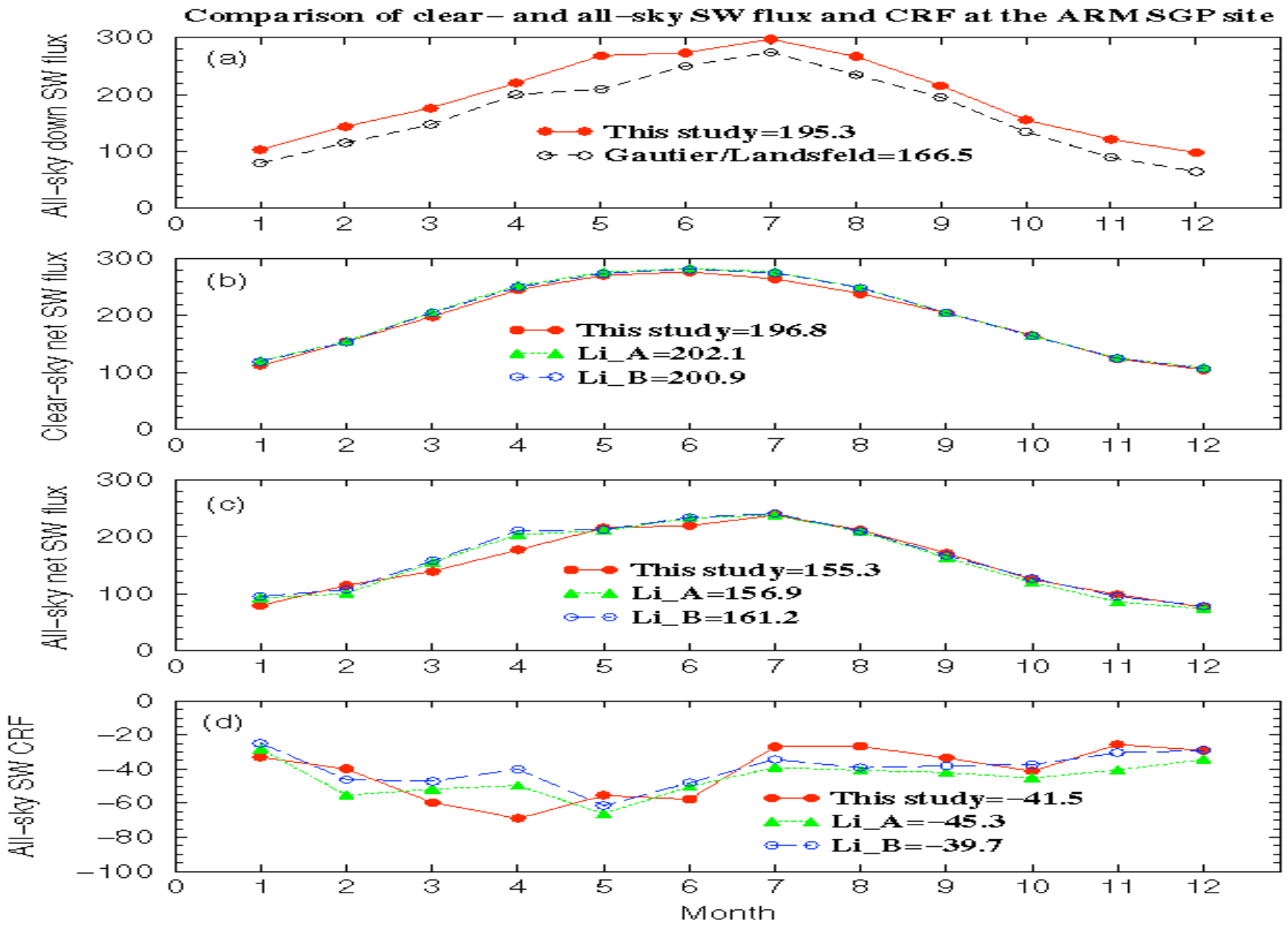


LW CRFs depend on cloud-base height/temp, and emissivity.
SW CRFs depend on solar insolation, optical depth and water vapor absorption.
Low clouds have largest LW and SW CRFs, strong cooling effect on the surface.
High clouds have least LW and SW CRFs, weak cooling effect on the surface.
From NET CRFs, (1) total/low clouds - strong cooling; (2) others – weak cooling.

Monthly variations of downwelling SW and LW fluxes at the ARM SGP site



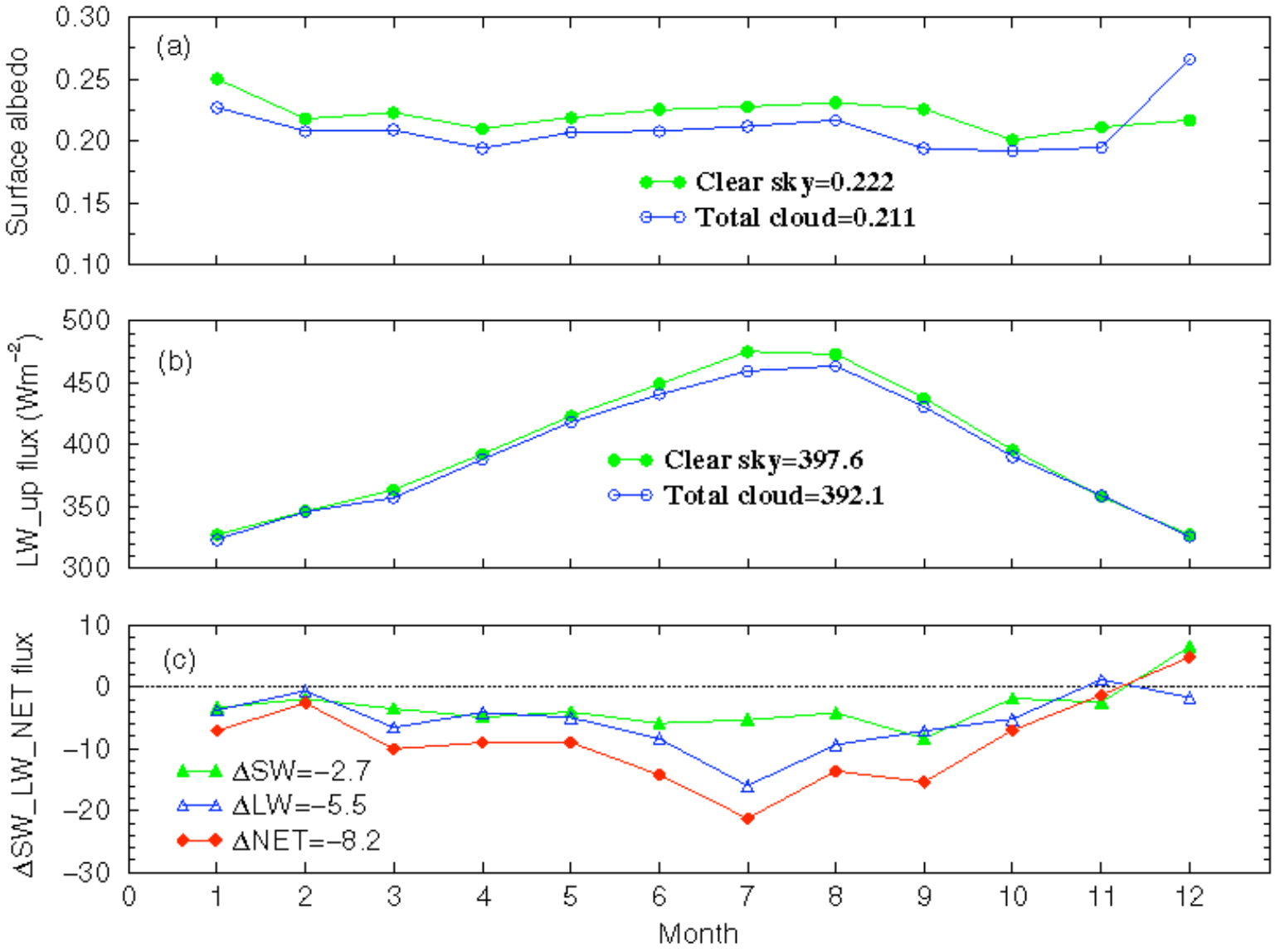
For SW flux, clear sky is greatest, low clouds have least due to optically thick, high clouds, all sky, middle clouds, and total clouds range from large to small. For LW flux, they are in the reverse order relative to SW flux.



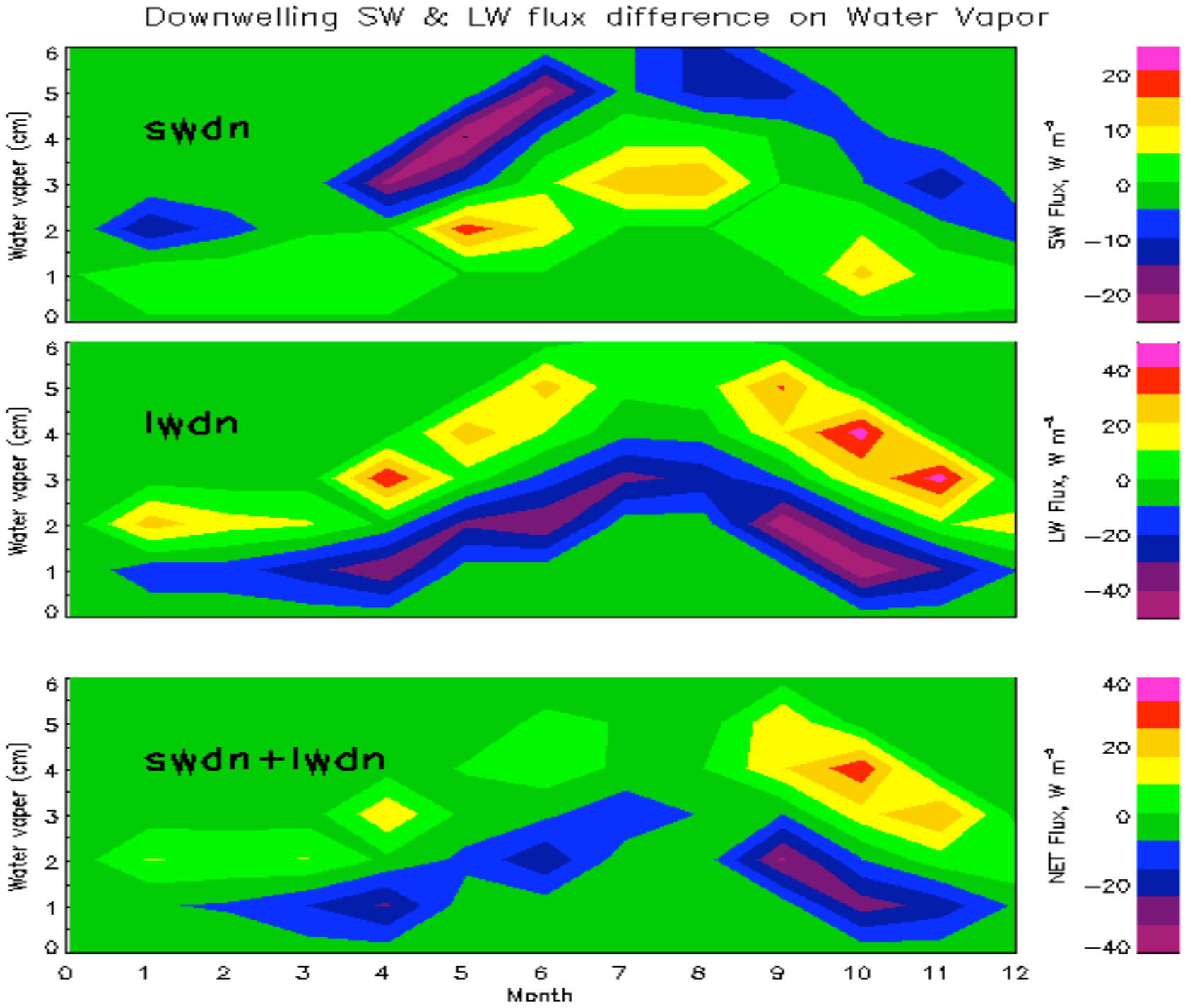
It is about 30 Wm^{-2} between this study and Gautier (GOES, from 03/97 to 04/94, excellent agreement with Li (ERBE, from 11/1984 to 12/1989).

Section 3: Uncertainties of SW and LW flux and CRF due to the background difference between clear sky and cloudy

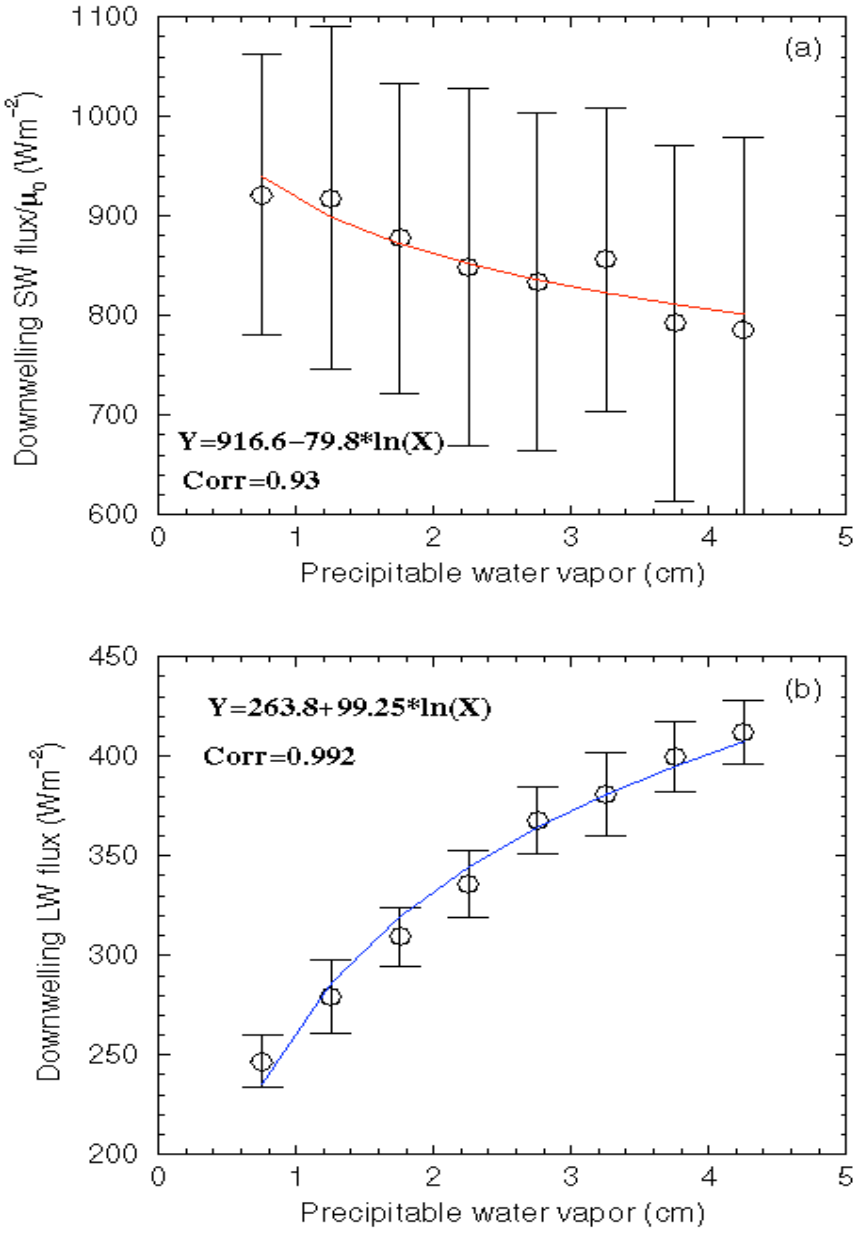
Monthly variations of surface albedo and tempreature, and atmospheric water vapor at the ARM SGP site

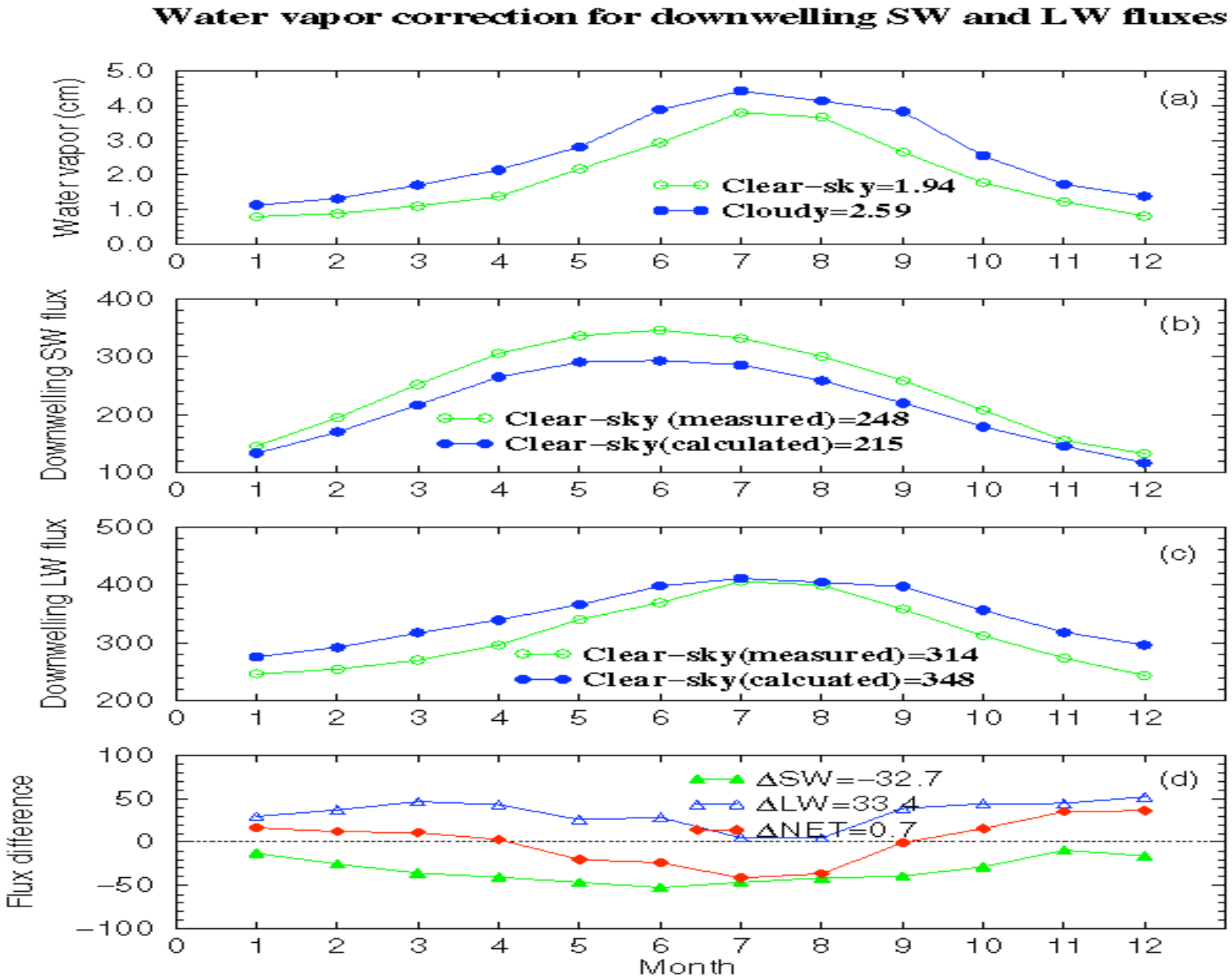


The current SW CRFs would be -2.7 Wm^{-2} lower, and LW CRFs -5.5 Wm^{-2} lower if we used cloudy surface albedo and upwelling LW flux.


Downwelling SW & LW flux difference on Water Vapor
swdn
lwdn
swdn+lwdn
Water vaper (cm)
Month
SW Flux, W m-2
LW Flux, W m-2
NET Flux, W m-2

Downwelling SW and LW vs. Water vapor at the ARM SGP site





Comparing to measured clear-sky fluxes, the corrected downwelling SW flux is about 33 Wm^{-2} less, and LW flux is about 33 Wm^{-2} more. They cancel out.

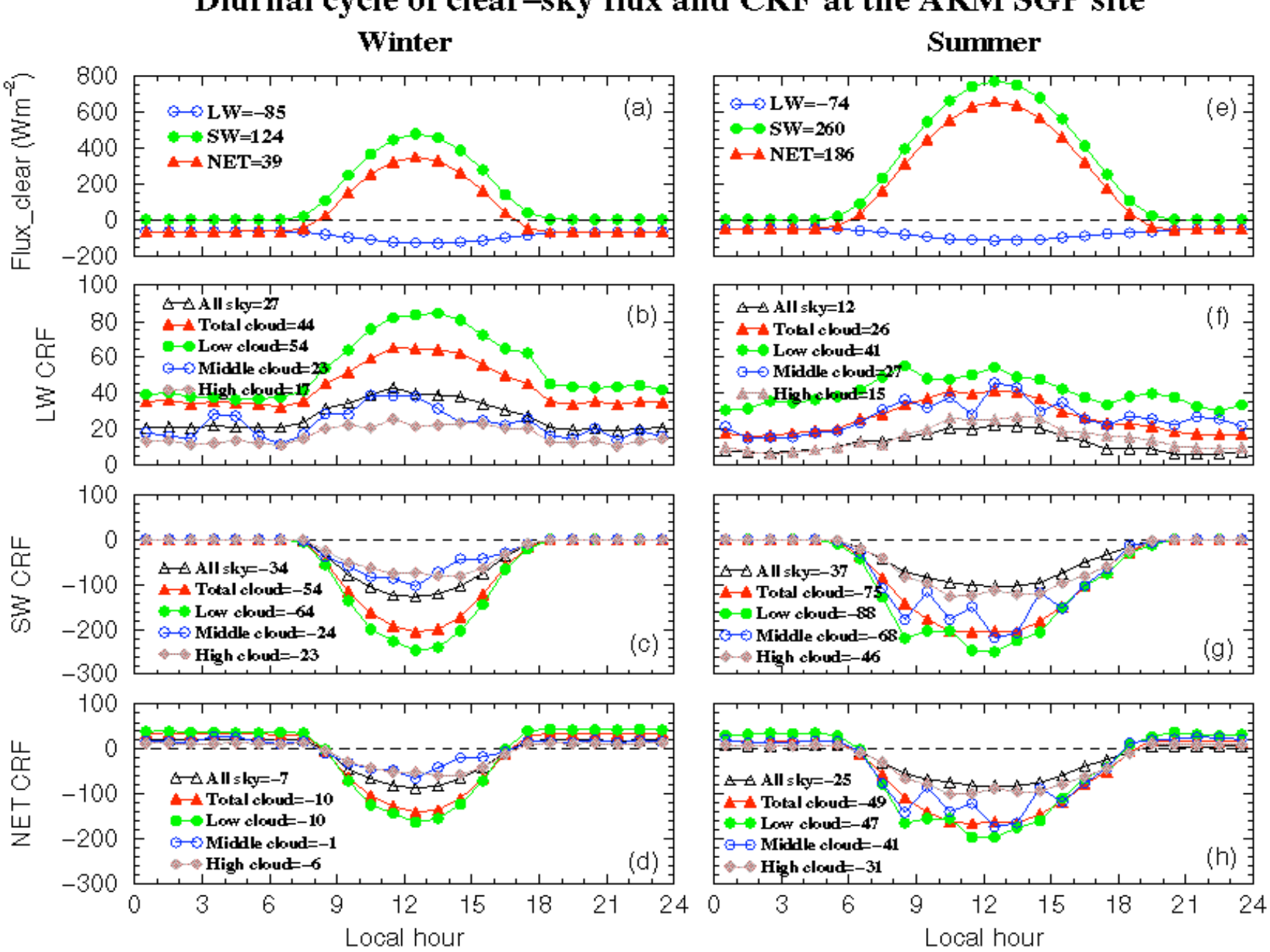
Conclusions

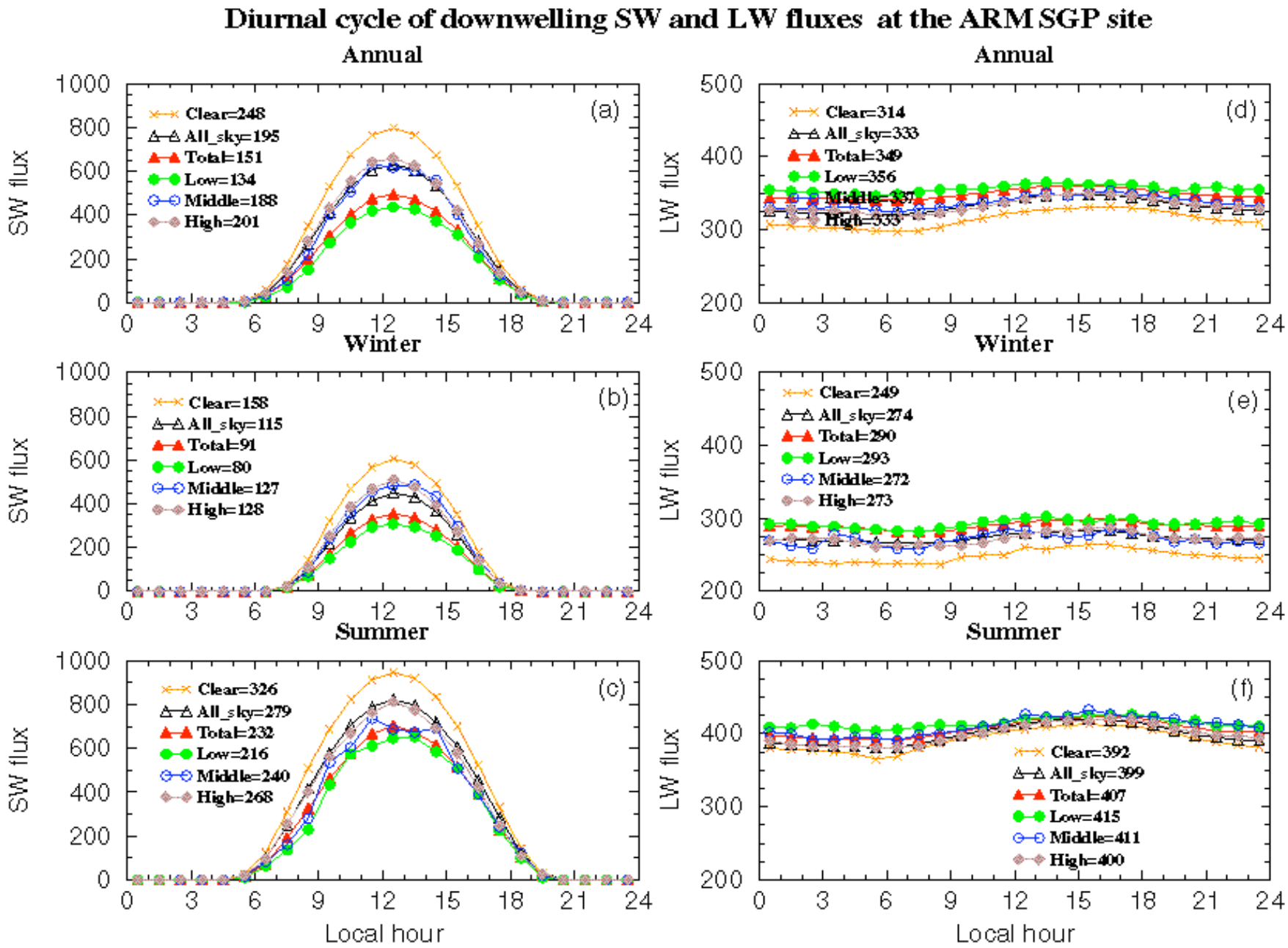
1) Cloud fraction: a) the total and low clouds occur greatest during winter and spring, and least often during summer; (b) the high clouds occur most in all four seasons than other types of clouds with a peak in summer; (c) the middle clouds occur least than others; and (d) the multilayer clouds are common.

2) According to their CRFs, clouds can be classified into 2 groups: the group 1 includes total and low clouds- strong SW cooling effect, large LW warming effect, and strong net cooling effect on surface; the group 2 includes all-sky, middle and high clouds- weak SW cooling, small LW warming, and weak net cooling effect on surface.

3) The NET CRFs would be slightly less (~8 Wm^{-2}) if the cloudy surface albedo and upwelling LW flux were used in the calculation of CRF. The annual NET CRFs should not be affected significantly by different clear-sky and cloudy backgrounds although the SW and LW CRFs may be more or less affected at individual month.


Thanks for your attention!


Diurnal cycle of clear–sky flux and CRF at the ARM SGP site
Winter
Summer
Flux_clear (Wm^{-2})
LW=–85
SW=124
NET=39
(a)
LW=–74
SW=260
NET=186
(e)
LW CRF
All sky=27
Total cloud=44
Low cloud=54
Middle cloud=23
High cloud=17
(b)
All sky=12
Total cloud=26
Low cloud=41
Middle cloud=27
High cloud=15
(f)
SW CRF
All sky=–34
Total cloud=–54
Low cloud=–64
Middle cloud=–24
High cloud=–23
(c)
All sky=–37
Total cloud=–75
Low cloud=–88
Middle cloud=–68
High cloud=–46
(g)
NET CRF
All sky=–7
Total cloud=–10
Low cloud=–10
Middle cloud=–1
High cloud=–6
(d)
All sky=–25
Total cloud=–49
Low cloud=–47
Middle cloud=–41
High cloud=–31
(h)
Local hour
Local hour


Diurnal cycle of downwelling SW and LW fluxes at the ARM SGP site
Annual
Clear=248
All_sky=195
Total=151
Low=134
Middle=188
High=201
(a)
SW flux
Annual
Clear=314
All_sky=333
Total=349
Low=356
Middle=327
High=333
(d)
LW flux
Winter
Clear=158
All_sky=115
Total=91
Low=80
Middle=127
High=128
(b)
Winter
Clear=249
All_sky=274
Total=290
Low=293
Middle=272
High=273
(e)
Summer
Clear=326
All_sky=279
Total=232
Low=216
Middle=240
High=268
(c)
Local hour
Clear=392
All_sky=399
Total=407
Low=415
Middle=411
High=400
(f)
Local hour

Vertical distributions of clouds at the ARM SGP site